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(54) Abstract Title
Gudgeon pin with a fused surface metal coating on a ceramic-reinforced metallic core

(57) The core is reinforced by distributed ceramic particles, or, as shown, by a ceramic fibre matrix structure 6. The fused coating 8 may be produced eg by metal spraying or vapour deposition. The composite gudgeon pin can have uniform or variable metal coating layer thicknesses on any surface and can have different layer thicknesses on different surfaces. The fused metal coatings can be unalloyed tool steel, alloyed tool steel, high speed steel, nitriding steel or iron. The distributed ceramic particles can be titanium diboride which is dispersed in a steel core, the primary forming process being forging. The ceramic fibre matrix 6 can be woven alumina matting into which pure aluminium 7 is infiltrated by a liquid infiltration process. The gudgeon pin can have drillings to conduct oil from an oil source in the connecting rod small end to the pin bosses. The gudgeon pin can be a conventional gudgeon pin, a slotted gudgeon pin for opposed piston engines with rockers and one crankshaft in which a rectangular end of the rocker slides in the slotted gudgeon pin, or a palm type gudgeon pin which is fixed rigidly to a connecting rod.

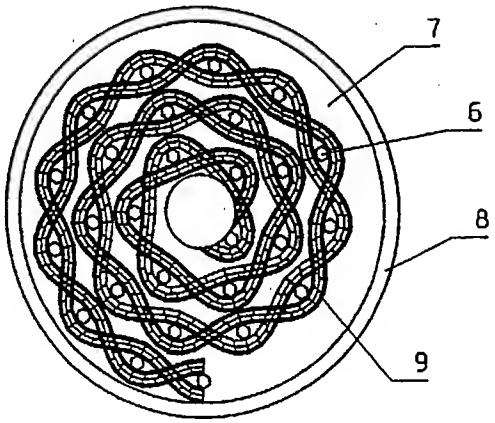

Fig 4a

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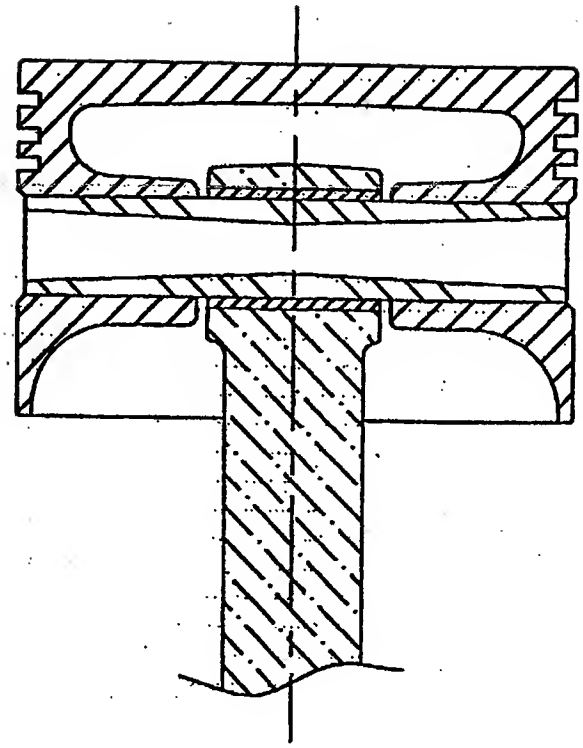

Fig: 1

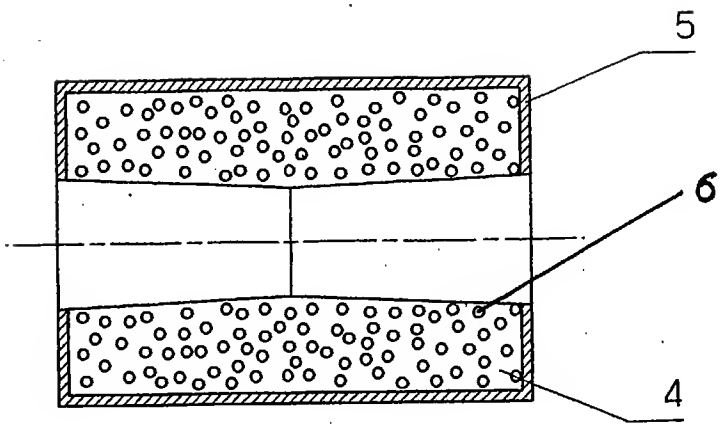

Fig 2a

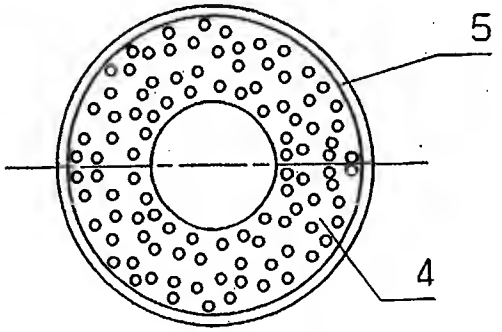

Fig 2b

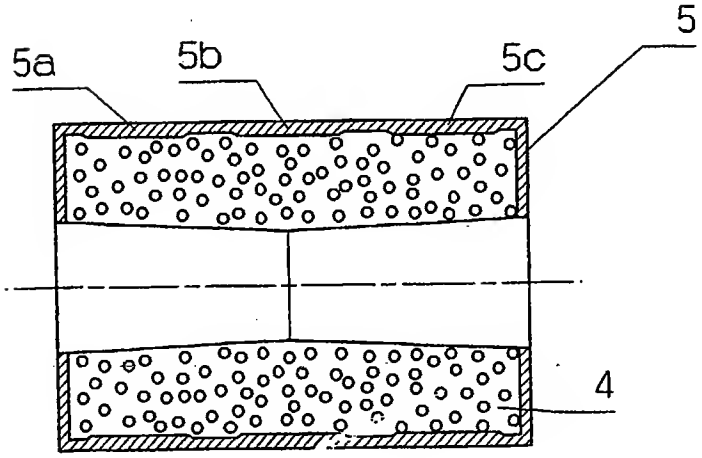

Fig 2c

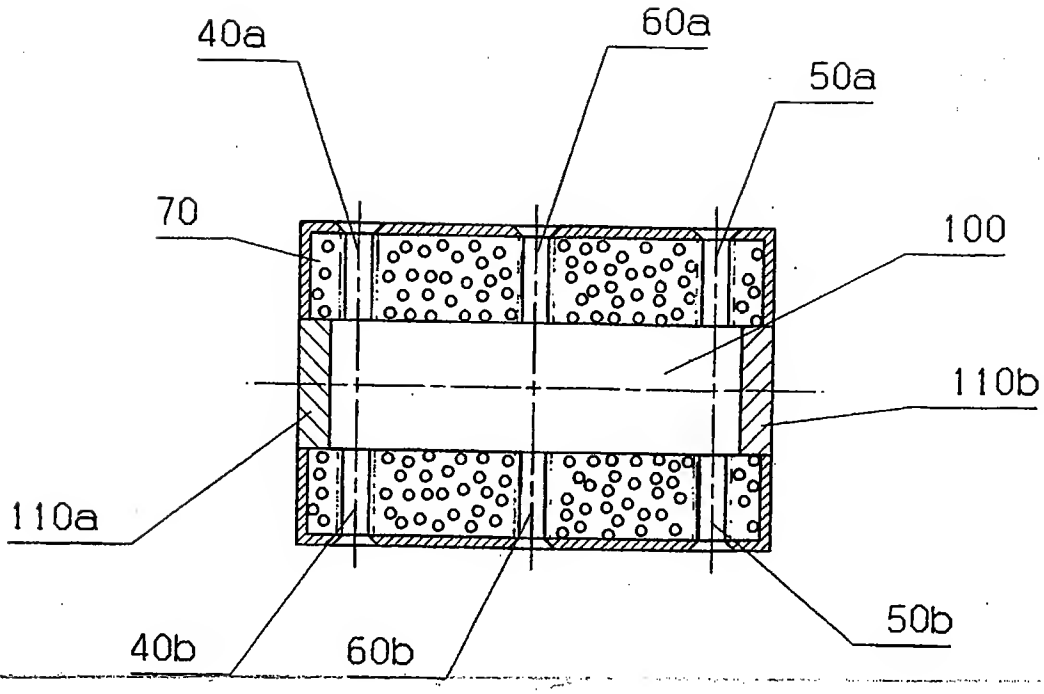

Fig 3a

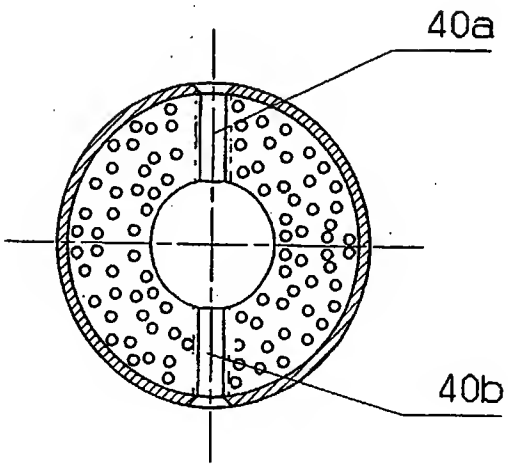

Fig 3b

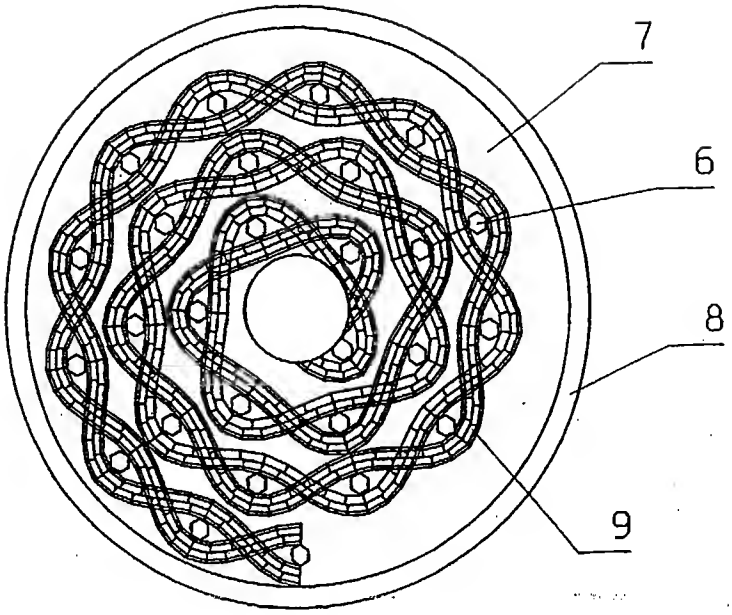

Fig 4a

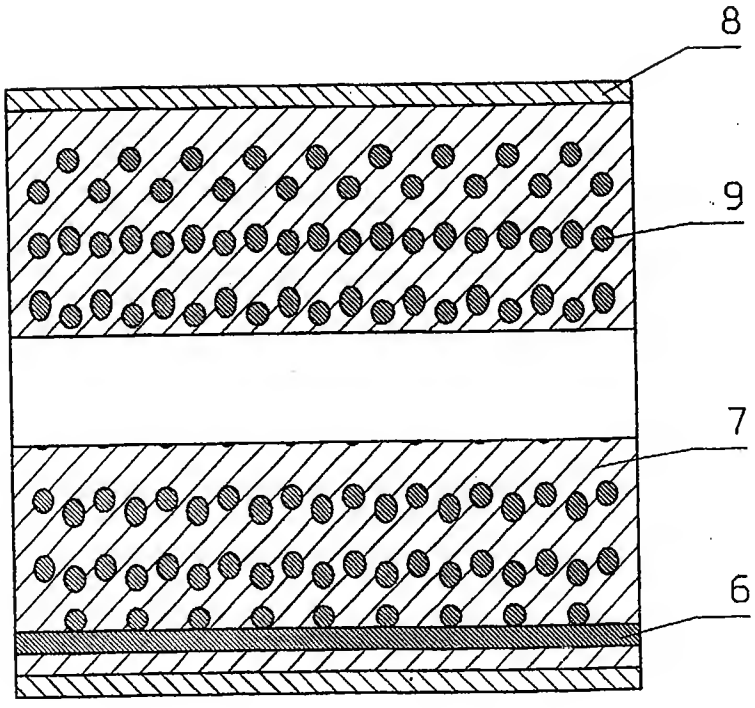

Fig 4b

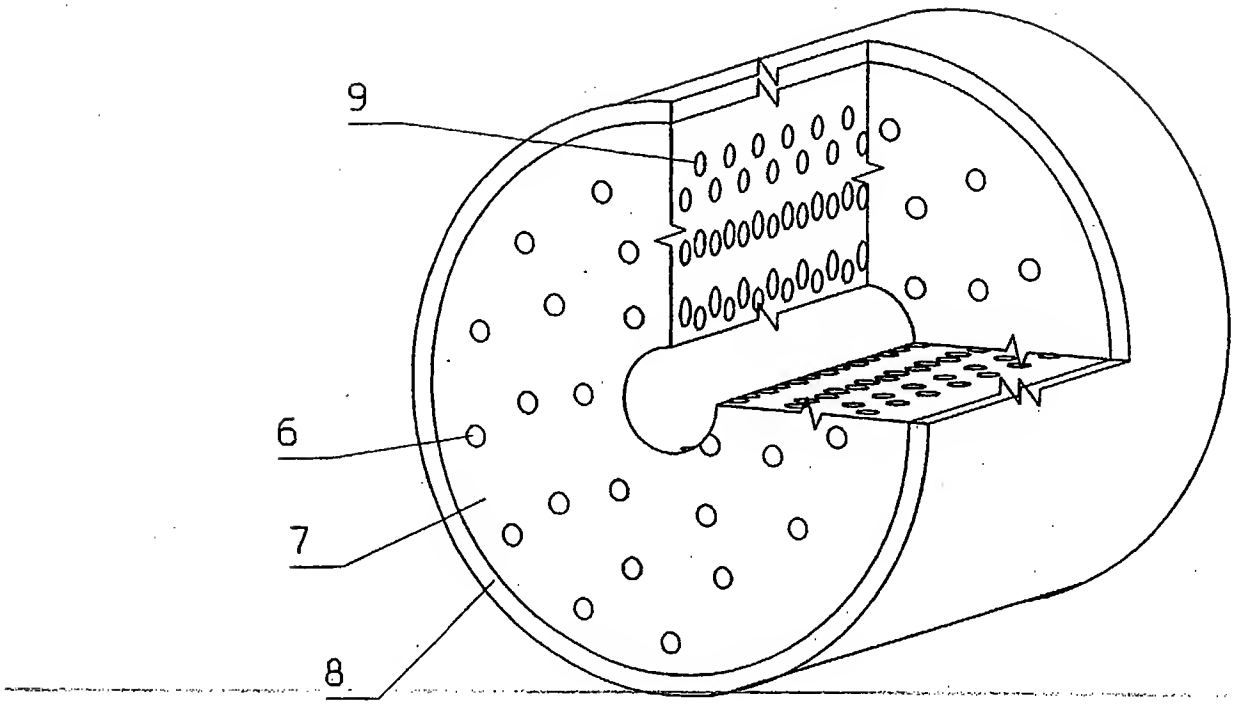

Fig 4c

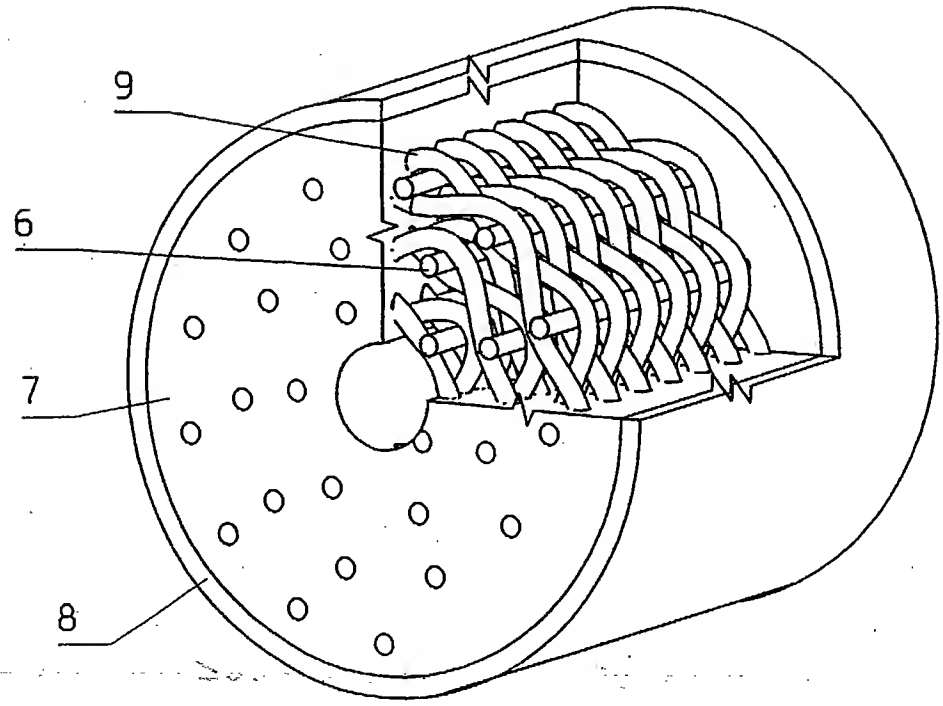

Fig 4d

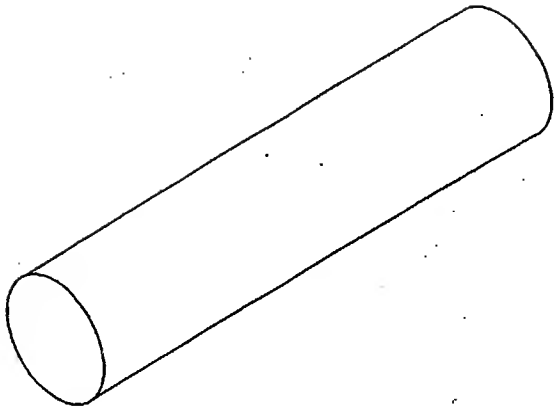

Fig 4e

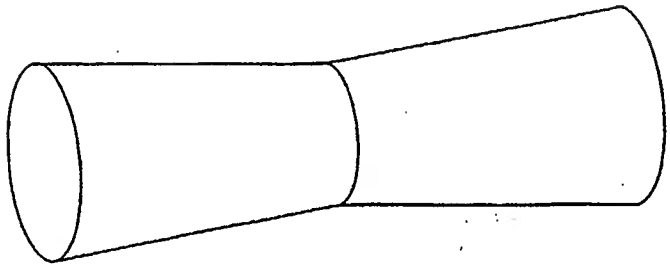

Fig 4f

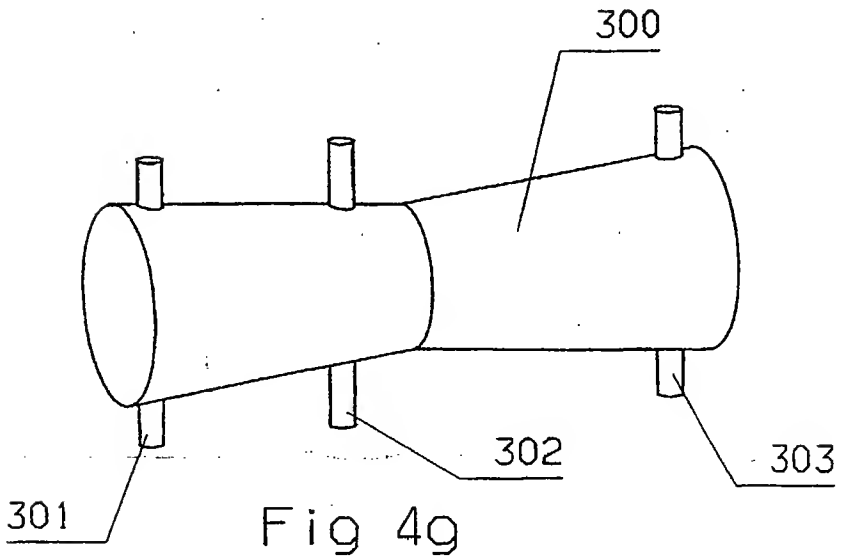

Fig 4g

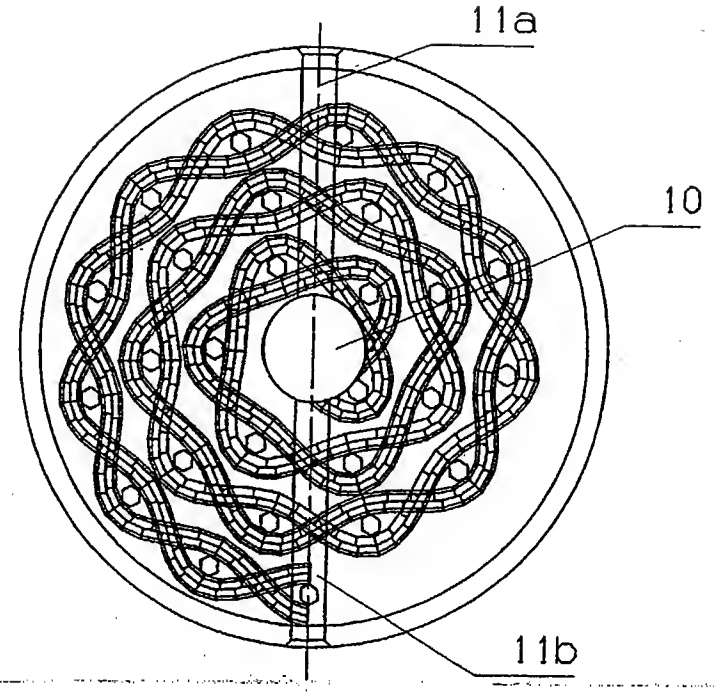

Fig 5a

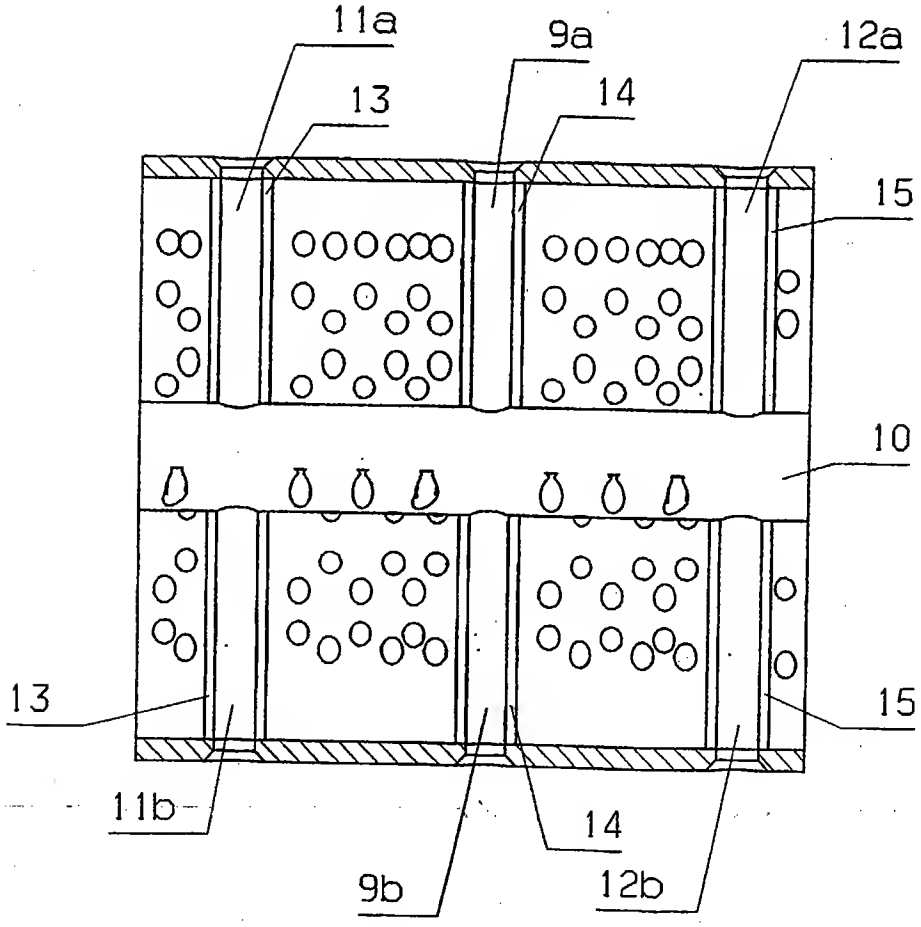

Fig 5b

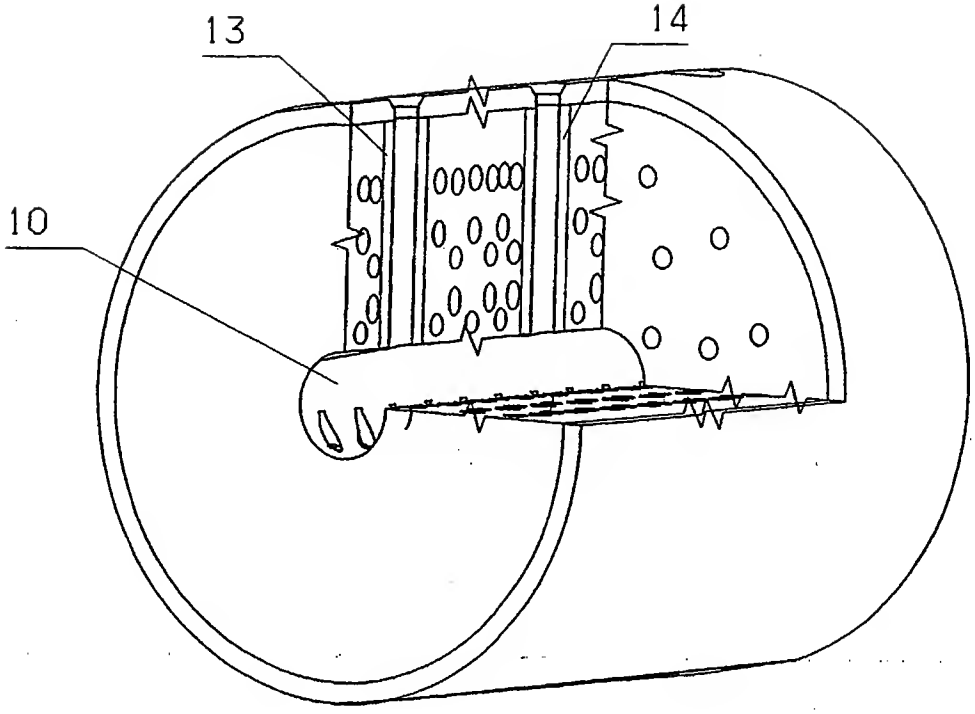

Fig 5c

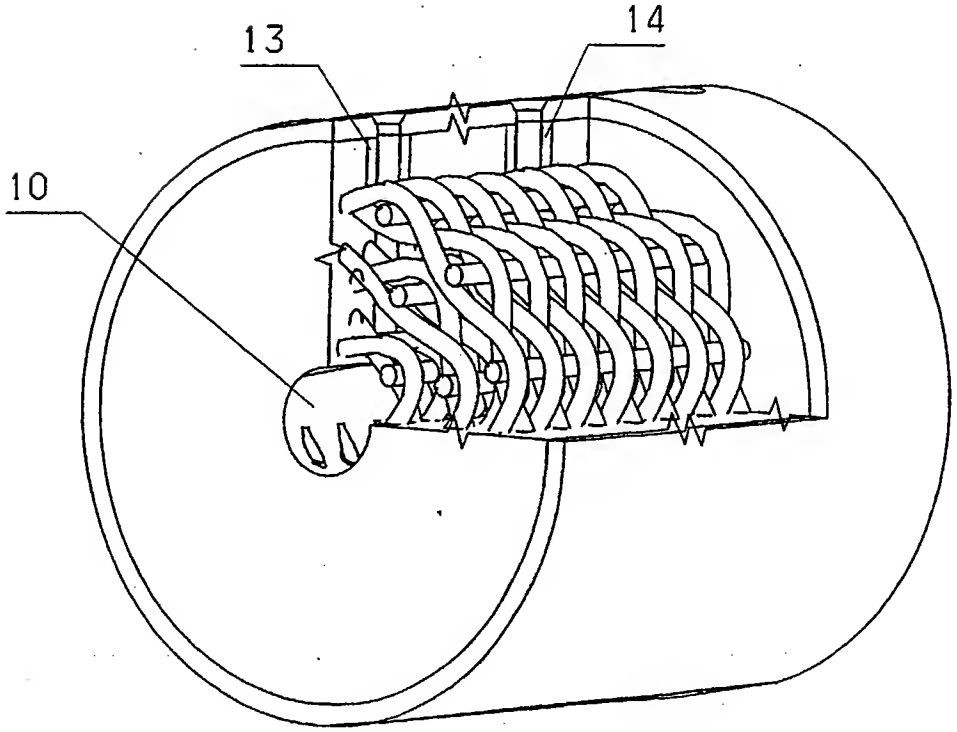

Fig 5d

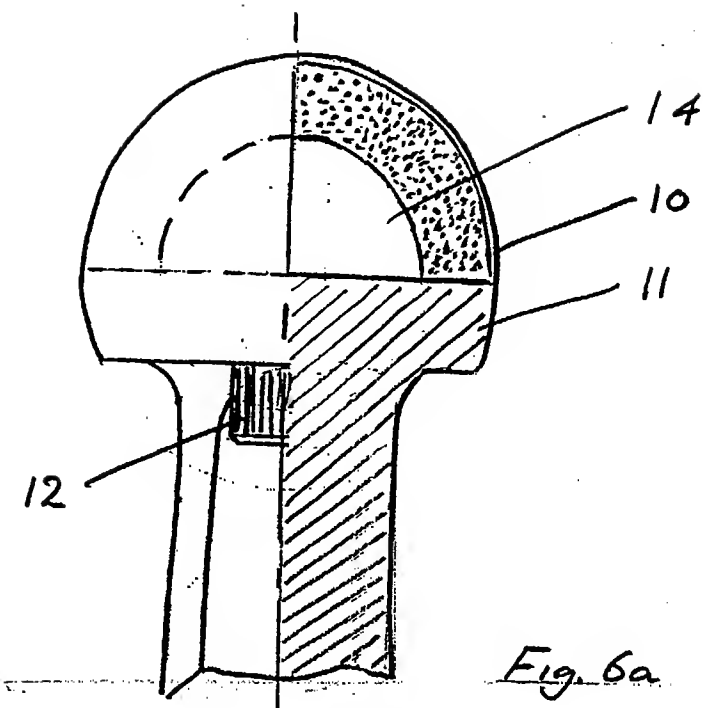

Fig. 6a

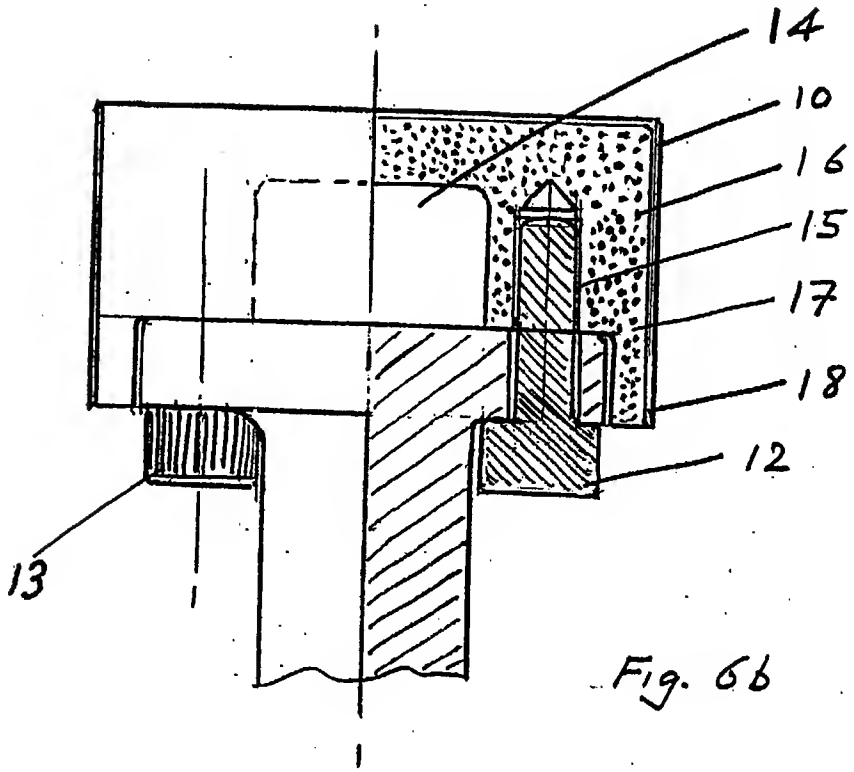

Fig. 6b

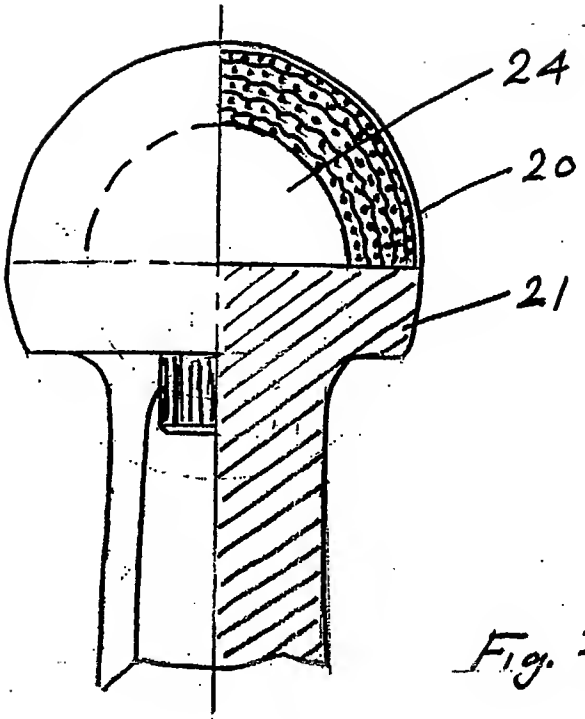

Fig. 7a

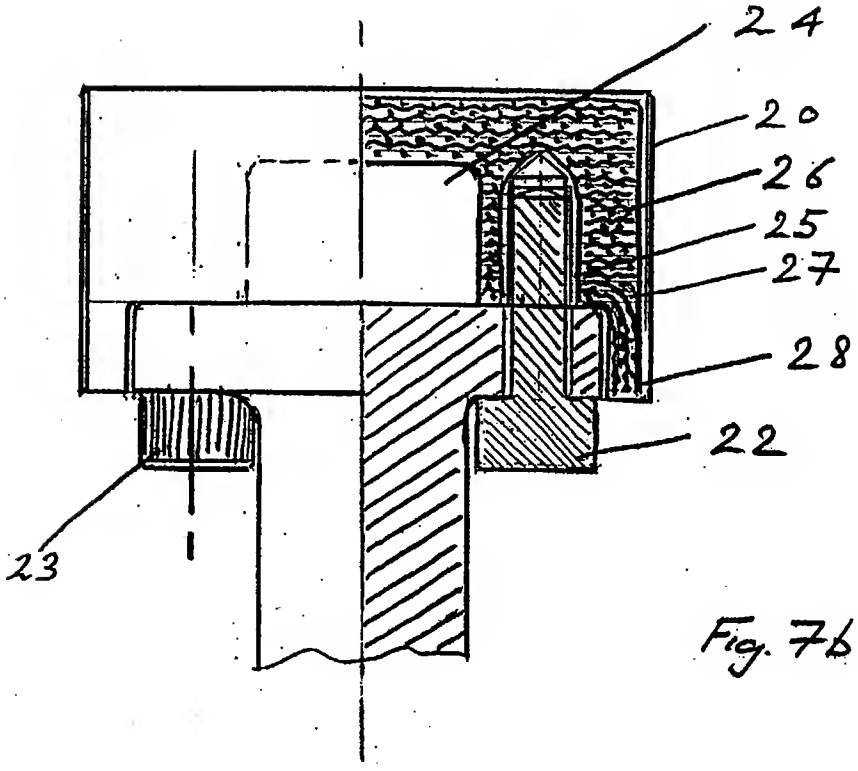

Fig. 7b

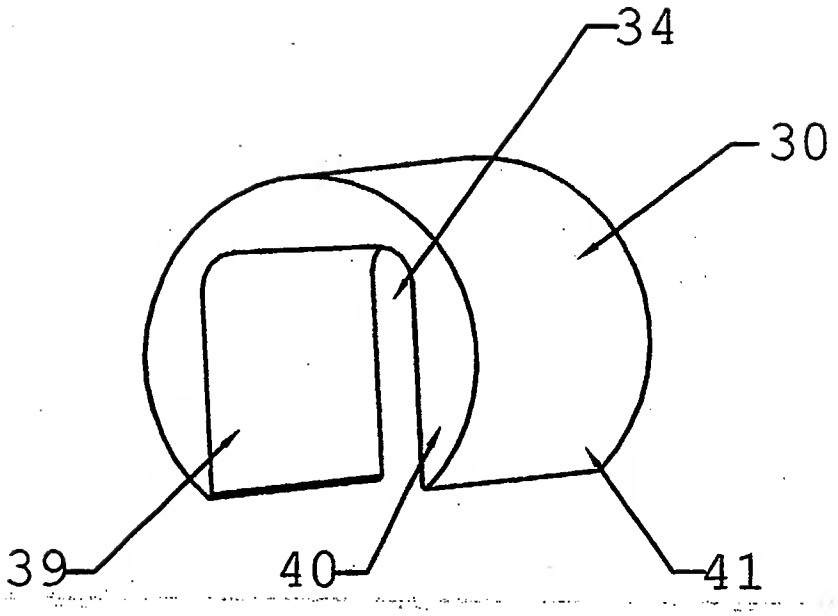

Fig. 8a

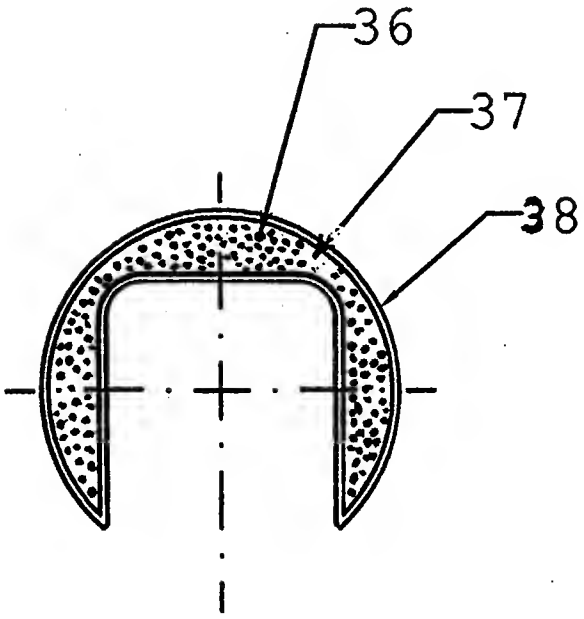

Fig. 8b

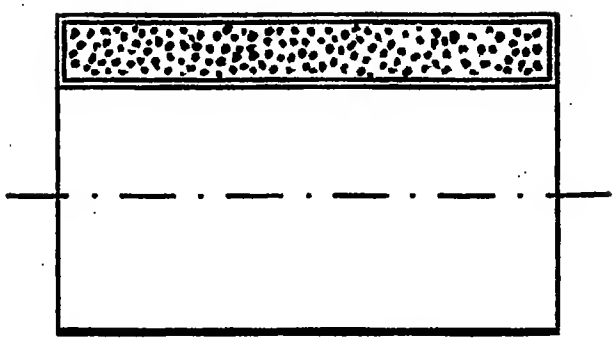

Fig. 8c

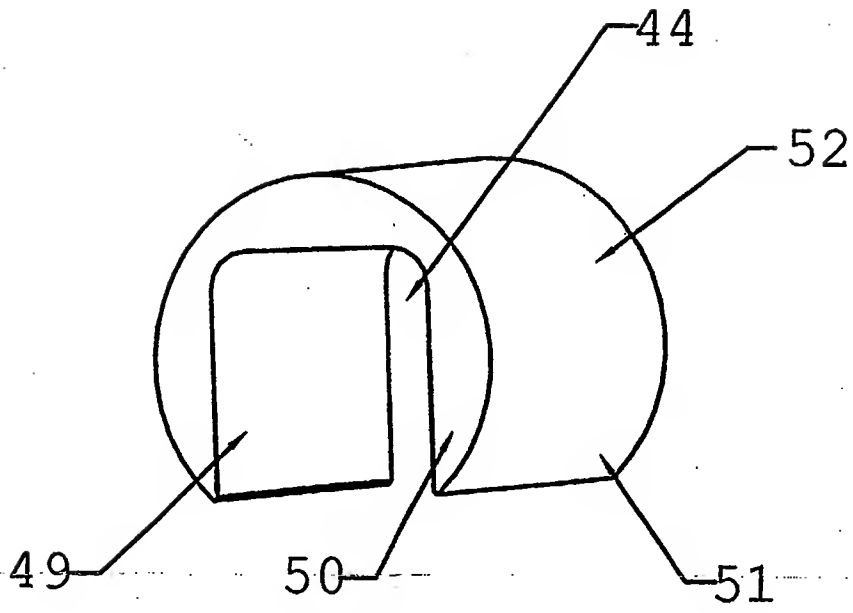

Fig. 9a

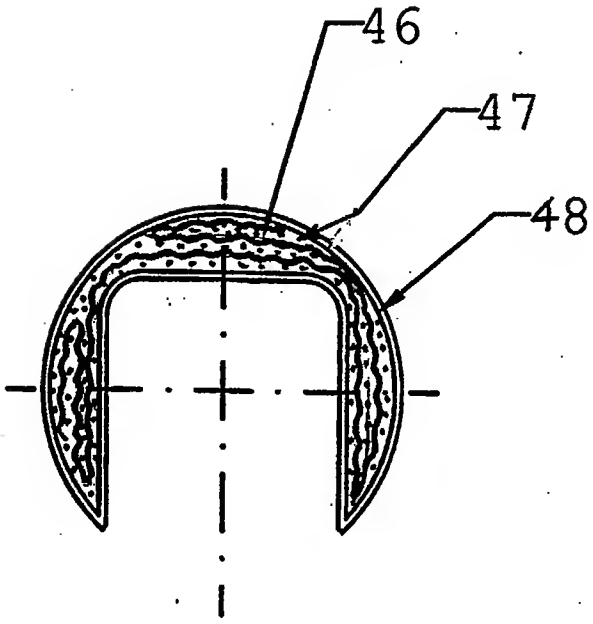

Fig. 9b

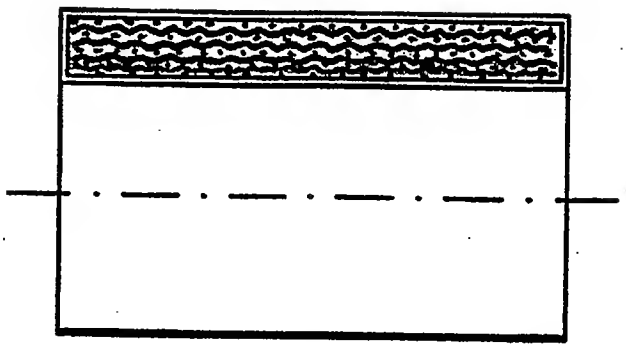

Fig. 9c

GUDGEON PIN comprising METALLIC CORE, reinforced with CERAMIC, and with FUSED HARD OUTER METAL COATING

The invention relates to gudgeon pins for use in reciprocating engines.

Gudgeon pins are usually made of high grade steels that have high modulus of elasticity, high strength and can be surface hardened to reduce wear with the piston boss and small-end bearing.

There are patents aimed at reducing the gudgeon pin mass by use of composite organic fibre reinforced resins, the hard outer coating being achieved with various types of steel sleeves.

The invention contemplates the use of a ceramic reinforcement of a metallic gudgeon pin . The presence of any of the ceramic on the surface of the gudgeon pin would create rapid abrasive wear of the contacting piston and small-end bearing surfaces. This problem is avoided by coating the functional surfaces of the gudgeon pin with a suitably and relatively hard and non abrasive material which is compatible with aluminium. The coating material effectively prevents the abrasive ceramic from contacting the piston whilst also providing a better and harder wear surface than the core metal material of the gudgeon pin.

In the broadest aspect as set out in Claim 1, the invention is a gudgeon pin comprising a core of metallic material, a ceramic reinforcement located within the core, and an external coating of a fused metal which is relatively harder than the core metal. The reinforcement can be either dispersed powder or in a contiguous matrix structure form. The fused coating can be produced by several possible processes such as metal spraying, laser melting of a cladding alloy, or vapour deposition whilst the reinforced core can be produced by forging or liquid metal infiltration, depending on the core material and the form of the ceramic reinforcement.

Other aspects of the invention are outlined in the further subordinate claims.

Background explanations and specific embodiments of the invention are now described by way of example with reference to the accompanying drawings in which:

Fig.1 shows a sectional elevation through a conventional piston, gudgeon pin and connecting rod assembly.

Figure 2a shows a longitudinal section through a first embodiment of the invention comprising a fused metal coated composite gudgeon pin with an alloyed metal core reinforced with dispersed ceramic particles.

Figure 2b shows a transverse section through the gudgeon pin of Fig.2a.

Fig. 2c is a variant of the gudgeon pin design shown in Fig.2a.

Figure 3a shows a longitudinal section through a second embodiment of the invention comprising a fused metal coated composite gudgeon pin with an alloyed metal core

reinforced with dispersed ceramic particles, the gudgeon pin having lubrication drillings.

Fig.3b is a transverse section through the drillings of the gudgeon pin of Fig.3a.

Figure 4a shows a transverse section through a third embodiment of the invention comprising a fused metal coated composite reinforced metallic gudgeon pin with a structured internal ceramic fibre matrix within the metal core.

Figure 4b shows a longitudinal section of the gudgeon pin of Fig.4a.

Fig.4c shows a perspective sectioned view of the gudgeon pin of Fig.4a, with a complete quadrant removed.

Fig. 4d shows a perspective sectioned view of the gudgeon pin of Fig.4a, with a quadrant partially removed and the material of the metal core and outer coating also removed, leaving the woven ceramic fibres exposed.

Fig.4e shows a cylindrical manufacturing mandrel used in the preparation of the reinforcement fibres prior to insertion in the liquid infiltration mould.

Fig.4f shows a split manufacturing mandrel in which each half is tapered.

Fig.4g shows a cylindrical manufacturing mandrel with substantially radial pins around its periphery.

Fig.5a is a tranverse section of a fourth embodiment of the invention comprising a composite metal coated gudgeon pin, with a structured internal ceramic matrix core, the gudgeon pin having lubrication drillings.

Figure 5b shows a longitudinal section of the gudgeon pin of Fig.5a.

Fig.5c shows a perspective sectioned view of the gudgeon pin of Fig.5a, with a complete quadrant removed.

Fig. 5d shows a perspective sectioned view of the gudgeon pin of Fig.5a, with a quadrant partially removed and the material of the metal core and outer coating also removed, leaving the woven ceramic fibres exposed.

Fig.6a is a half end view and tranverse section of a fifth embodiment of the invention comprising a composite metal coated palm type gudgeon pin, with dispersed ceramic particles.

Figure 6b shows a part longitudinal view and part longitudinal section of the palm gudgeon pin of Fig.6a.

Fig.7a is a half end view and tranverse section of a sixth embodiment of the invention comprising a composite metal coated palm type gudgeon pin, with a structured

With reference to Fig.4d, this shows the quadrant section with the ceramic fibre matrix still in position; it is clear from this view that the longitudinal and cross weave circumferential fibres are orthogonal to each other. It is also possible to have arrangements of the composite metallic gudgeon pin where the circumferential fibres are orientated at less than 90° to the longitudinal fibres that are parallel to the major axis of the gudgeon pin so that both directions of weave can contribute to the longitudinal stiffness of the gudgeon pin, and these non-orthogonal circumferential fibre arrangements provide reinforcement continually along the length of the gudgeon pin, in contrast to the effectively truncated longitudinal reinforcement of the transverse fibres shown in Fig.4c. A typical cross-weave angle could be 45 degrees to the longitudinal fibres.

With reference to Fig.4e, the manufacturing mandrel onto which the ceramic fibre matting is wound prior to pre-impregnation has an outer diameter which is nominally equal to the inner diameter of the finished gudgeon pin.

With reference to Fig.4f, it is also possible to have a split manufacturing mandrel that can be used to ease the removal of the mandrel from the pre-impregnated matting. In this case the mandrel also has taper on each half, further facilitating removal of the mandrel from the impregnated matting, and also allowing the use of gudgeon pins with substantially tapered sections from the centre outwards, a common weight saving feature.

With reference to Fig.4g, this shows a manufacturing mandrel which comprises the central longitudinal core 300 into which are fitted removable, tight fitting radial pins 301, 302 and 303 which are slightly larger in diameter than any required oil drilling in the gudgeon pin. The pins are longer than the radial drilling length, enabling them to be removed from the mandrel after the pre-impregnating process. The pins may also have tapered leading ends to facilitate the loading of the matting over the pins onto the manufacturing mandrel.

With reference to Figs. 5a & 5b, this shows a sectional elevation of a composite gudgeon pin with passages for oil transfer. Passages 9a and 9b receive oil from the small-end of the connecting rod and pass the oil, via the main gallery 10, to the exit oil passages 11a, 11b, 12a and 12b to lubricate the piston pin bosses. The main gallery 10 is closed at both end by inserts (not shown in Figs.5a-d), similar to those shown (110a and 110b) in Fig.3a. The matrix reinforcement insert in this case has radial cylindrical passages 13, 14 and 15 where there is solid metal, ie without the reinforcement fibres. This facilitates drilling of the oil passages since when the insert is filled with metal to make the core, the passages 13, 14 & 15 are filled only with the metal. Thus oil passage drilling only occurs through the thin outer metal coating and in the relatively soft filler aluminium or other lightweight metal material, and not through the hard fibres of the matrix.

With reference to Fig.5c, this shows sections through the circumferential fibres of the gudgeon pin shown in Figs.5a & 5b, the sectioning plane being such that it does not intersect any longitudinal fibres; this is why no longitudinal fibres are visible in the sectionned quadrant.

With reference to Fig.5d, this shows a part quadrant section of the gudgeon pin shown in Fig.5a & b, but the fibre windings have been left in position without the surrounding metal core in order to show the woven construction of the fibres. This woven matt winding would be performed on an inner removable mandrel. The wound material is then impregnated with a fixing agent to maintain the wound shape of the fibre matrix; the mandrel is then removed and the fibre matrix inserted into the liquid metal infiltration mould.

With reference to Fig.6a and 6b, this shows a palm gudgeon pin 10 which is attached to the connecting rod 11 with bolts 12 & 13 which are screwed into tapped holes 15; consequently, this type of gudgeon pin cannot rotate relative to the connecting rod but offers more pin boss load area to take gas loading on the piston. The gudgeon pin may be solid or have a hollow centre 14. The dispersed ceramic particles 16 are shown in the core material 17 with the relatively hard fused outer coating 18 covering the outer surface of the palm gudgeon pin. This arrangement may have an oil feed from the connecting rod into the hollow of the gudgeon pin which connects with drillings to the outer surface of the gudgeon pin.

With reference to Fig.7a and 7b, this shows a palm gudgeon pin 20 which is attached to the connecting rod 21 with bolts 22 & 23 which are screwed into tapped holes 25. The gudgeon pin may be solid or have a hollow centre 24. The structured ceramic matrix fibres 26 are shown in the core material 27 with the relatively hard fused outer coating 28 covering the outer surface of the palm gudgeon pin. The ceramic matrix can be formed by wrapping layers of 2 dimensional matting around an inner fixing mandrel that corresponds to the inner void 24 and over fixing pegs that correspond to the bolt fixing holes 25. The drill holes 25 may either be cast solid with the core material to allow easy drilling, or during the casting process, die pegs are used which may be of a smaller diameter and length than the fixing pegs, leaving a blank hole with relatively soft core material for drilling and tapping.

The arrangement of Fig.7a and 7b may have an oil feed from the connecting rod into the hollow of the gudgeon pin which connects with drillings to the outer surface of the gudgeon pin.

With reference to Fig.8a, 8b and 8c, this shows a slotted gudgeon pin 30 which is used in certain opposed piston 2-stroke engines where an engaging rocker arm has a rectangular section small end that slides into the slot 34 of the gudgeon pin 30; the motion of the piston and gudgeon pin are substantially orthogonal to the end of the rocker arm so that the mechanism has no tendency to separate.

The dispersed ceramic particles 36 are shown in the core material 37 with the relatively hard fused outer coating 38 covering the inner 39,outer 41 and end surfaces 40 of the slotted gudgeon pin. This arrangement may have an oil feed from the rocker arm end into the volume bounded by the inner surface 39 of the slotted pin and the end of the rod and thence to the outer surface 41 via drillings (which are not shown). Oil loss from the ends of the slotted gudgeon pin is prevented by closing plates that are held, by some fixing such as circlips, between the ends of the gudgeon pin and the periphery of the piston.

With reference to Fig.9a, 9b and 9c, this shows a slotted gudgeon pin 52 which is used in certain opposed piston 2-stroke engines where the connecting rocker arm has a rectangular section small end that slides into the slot 44 of the gudgeon pin 52; the motion of the piston and gudgeon pin are substantially orthogonal to the end of the connecting rocker arm so that the mechanism has no tendency to separate.

The fibres of the ceramic matrix 46 are shown in the core material 47 with the relatively hard fused outer coating 48 covering the inner 49, outer 51 and end surfaces 50 of the slotted gudgeon pin. The ceramic fibre matting 46, in this particular embodiment, may be formed by wrapping the matting in alternate directions around a mandrel that corresponds to the shape of the slot. This arrangement may have an oil feed from the connecting rocker arm end into the volume bounded by the inner surface 49 of the slotted pin and the end of the rod and thence to the outer surface 51 via drillings (which are not shown). Oil loss from the ends of the slotted gudgeon pin is prevented by closing plates that are held, by some fixing such as circlips, between the ends of the gudgeon pin and the periphery of the piston.

CLAIMS

1 A metallic gudgeon pin comprising a core of metallic material, a ceramic reinforcement located within the core, and an external coating of fused metal which is relatively harder than the metallic material of the core.

2 A gudgeon pin as claimed in Claim 1 in which the coating is fused alloyed tool steel.

3 A gudgeon pin as claimed in Claim 1 in which the coating is fused unalloyed tool steel.

4 A gudgeon pin as claimed in Claim 1 in which the coating is fused high speed tool steel.

5 A gudgeon pin as claimed in Claim 1 in which the coating is fused nitriding steel.

6 A gudgeon pin as claimed in Claim 1 in which the coating is fused iron.

7 A gudgeon pin as claimed in any preceding claim in which the core is of aluminium.

8 A gudgeon pin as claimed in any of Claims 1-6 in which the core is steel.

9 A gudgeon pin as claimed in any of Claims 1-6 in which the core is alloyed steel.

10 A gudgeon pin as claimed in any preceeding claim in which the core is reinforced by dispersed ceramic powder.

11 A gudgeon pin as claimed in claim 10 in which the ceramic powder is titanium diboride.

12 A gudgeon pin as claimed in any of Claims 1-7 in which the core is reinforced by a ceramic fibre matrix.

13 A gudgeon pin as claimed in Claim 12 in which the ceramic fibre matrix is of a woven matting

14 A gudgeon pin as claimed in Claim 12-13 in which the ceramic fibre matrix is of alumina.

15 A gudgeon pin as claimed in Claim 12-13 in which the ceramic fibre matrix is of boron.

16 A gudgeon pin, as claimed in any of Claims 13-15, in which the ceramic fibre matrix is a woven orthogonal matting having the majority of the fibres aligned substantially in the longitudinal axis of the gudgeon pin.

17 A gudgeon pin, as claimed in Claims 13 - 15, where the ceramic fibre matrix is a woven matting having some fibres aligned at 45° to the longitudinal axis of the gudgeon pin.

18 A gudgeon pin, as claimed in any of the preceding claims, in which oil feed holes extend from the interior surface to the exterior surface of the gudgeon pin.

19 A gudgeon pin, as claimed in any of the preceeding claims, in which the fused coating extends over only part of the external surfaces of the pin.

20 A gudgeon pin, as claimed in Claims 1-18, in which the fused coating extends over all of the external surfaces of the pin.

21 A gudgeon pin, as claimed in any of any of Claims 1-20, in which the fused coating is of uniform thickness over the gudgeon pin surface.

22 A gudgeon pin, as claimed in any of Claims 1-20, in which the fused coating is of non-uniform thickness over the gudgeon pin surface.

23 A gudgeon pin, as claimed in any preceeding claim, in which the fused coating is formed by metal spraying or vapour deposition.

24 A gudgeon pin, as claimed in Claims 10-11, or Claims 18-23 when not dependent on Claim 7 or Claims 12-17, in which the core is made by a forging process.

25 A gudgeon pin, as claimed in any of Claims 1-7, 12-23, in which the core is made by a liquid infiltration die casting process.

26 A gudgeon pin, as claimed in Claim 25, in which the liquid infiltration process is assisted by a vacuum applied to the die or mould.

27 A gudgeon pin, as claimed in Claims 1-26, in which the gudgeon pin is fixed to the connecting rod so that it cannot rotate relative to the connecting rod.

28 A gudgeon pin, as claimed in Claims 1-26, which has a slot into which slides a rectangular sectioned small end of a rocker.

29 A gudgeon pin, as Claimed in Claims 25-26, in which the fibre matting is shaped on a cylindrical mandrel prior to inserting in the die for liquid infiltration.

30 A gudgeon pin, as Claimed in Claims 25-26, in which the fibre matting is shaped on a split tapered cylindrical mandrel prior to inserting in the die for liquid infiltration.

31 A gudgeon pin, as Claimed in Claims 25-26, in which the fibre matting is shaped on a split tapered cylindrical mandrel, with slideable radial pegs, prior to inserting in the die for liquid infiltration.

32 A gudgeon pin substantially as herein described with reference to Figs. 2a-2c.

33 A gudgeon pin substantially as herein described with reference to Figs. 3a-3b.

34 A gudgeon pin and manufacturing means substantially as herein described with reference to Figs. 4a-4g.

35 A gudgeon pin substantially as herein described with reference to Figs. 5a-5d.

36 A gudgeon pin substantially as herein described with reference to Figs. 6a, 6b.

37 A gudgeon pin substantially as herein described with reference to Figs. 7a, 7b

38 A gudgeon pin substantially as herein described with reference to Figs. 8a-c

39 A gudgeon pin substantially as herein described with reference to Figs. 9a-c.

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Claims searched: 1 to 39

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Databases searched:

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Other: online: EPODOC, JAPIO, WPI, FULL-TEXT

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	JP 62-049073 A	(Yamaha) - see Patent Abstracts of Japan, vol.011235, group M612	1,7,12,14, 20 at least
X	JP 60-078164 A	(Toyota) - see Patent Abstracts of Japan, vol.009219, group M410; WPI abstract accession no.1985-143845	1,7,12,20, 23,29 at least
A	JP 4-171365 A	(Toyota) - see Patent Abstracts of Japan, vol.016474, group M1319	
A	JP 61-024877 A	(Toyota) - see Patent Abstracts of Japan, vol.010176, group M491	

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